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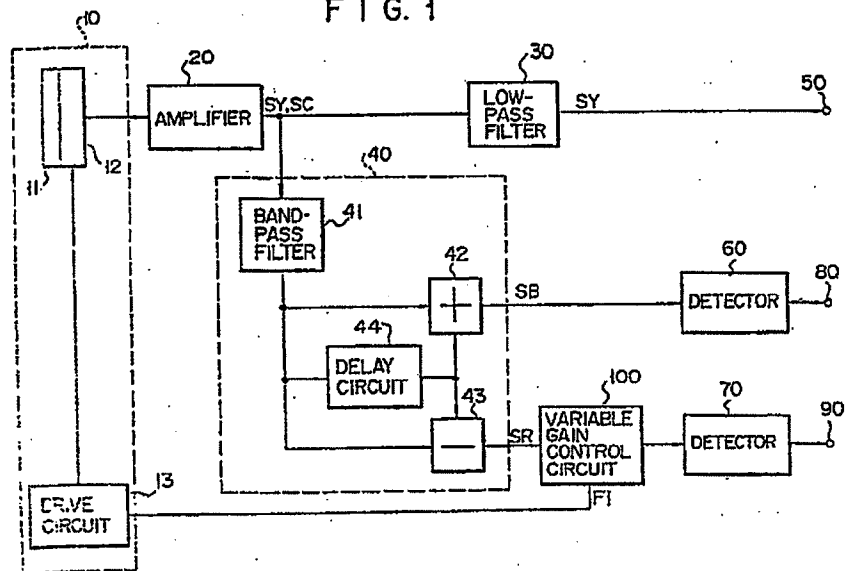
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(54) Color imaging apparatus.

(57) An electrical signal of a subject image which is outputted from an image pickup section (10) is given to a chrominance signal separating section (40) through an amplifier (20). In this chrominance signal separating section (40), the adding and subtracting processes of a signal in the present horizontal scan line and a signal in the horizontal scan line which was scanned 1H before are performed, so that a blue signal (SB) and a red signal (SR) which are included in the electrical signal are respectively outputted from an adder (42) and a subtractor (43). Between these two signals (SR) and (SB), the red signal (SR) whose amplitude level varies for every field is supplied through a variable gain control circuit (100) whose gain is controlled by a field index signal (FI), so that the level of the red signal (SR) is controlled such that the amplitude levels in the odd fields (OF) and even fields (EF) are equal.

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FIG. 1



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Color imaging apparatus

The present invention relates to a color imaging apparatus using a solid-state image pickup device as, for example, an image pickup device for converting an optical signal to an electrical signal.

5 In conventional color imaging apparatuses, most of them use an image pickup tube (camera tube) as an image pickup device. However, recently, a color imaging apparatus using a solid-state image pickup device such as a CCD (charge coupled device) type
10 image pickup device has been developed.

 In the color imaging apparatus using a solid-state image pickup device, a photo sensitive section for storing charges responsive to the strength of light can be formed in each pixel. Due to this, as a color
15 filter array which is arranged on the side of the incident light section of the image pickup device, it is possible to use arrays of various formats in which the kind and arrangement of color filters differ. Thus, this makes it possible to use a new color filter
20 array which could not be used in the color imaging apparatus employing the image pickup tube, so that it is possible to realize a new image pickup method which could not be realized by the color imaging apparatus using the image pickup tube.

25 When attention is paid to a method of taking out an electrical signal of a one-frame image as

an image pickup method, in the color imaging apparatus using the solid-state image pickup device, not only the frame pickup method but also the field image pickup method can be easily realized. In the frame
5 image pickup method, the electrical signal is produced from the photo sensitive section at a frame period. In the field image pickup method, on the other hand, the electrical signal is produced from the photo sensitive section at a field period.

10 In addition, in the color imaging apparatus using the solid-state image pickup device, even when the number of pixels is small, an image with high resolution can be obtained by appropriately setting the kind and arrangement of color filters in the color filter array.

15 However, in the solid-state imaging apparatus using the solid-state image pickup device, the above-mentioned advantage is obtained, but there is, contrarily, a problem such that a color flicker at a frame frequency (30 Hz in an NTSC system) is likely to
20 occur in the image. As the causes for occurrence of this color flicker, it is possible to mention, for instance, relative positional deviation between each color filter and the pixel corresponding thereto, variations in characteristics (transmittancy, spectral
25 factor, etc.) of the color filters, and crosstalk of the stored charges between the pixels.

It is an object of the present invention to provide a color imaging apparatus which can prevent the occurrence of color flicker and the prevention of this
30 color flicker can be realized by merely adding a simple circuit to the existing apparatus.

According to the invention, a novel color imaging apparatus is provided.

To accomplish the above object, the invention is
35 constituted in a manner such that a level change for every field is eliminated by controlling the amplitude level of the separated output of a chrominance signal

for every field.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

5 Fig. 1 is a circuit diagram showing an arrangement of one embodiment according to the present invention;

Fig. 2 is a diagram showing one example of a color filter array shown in Fig. 1;

10 Fig. 3 is a diagram showing the storage state of charges on the n -th horizontal scan line in the odd fields when the color filter array as shown in Fig. 2 is used;

15 Figs. 4 to 6 are diagrams showing the storage states of the charges shown in Fig. 3 with regard to the green light, red light and blue light, respectively;

Fig. 7 is a diagram showing the storage state of charges on the $(n+1)$ th horizontal scan line in the odd fields when the color filter array as shown in Fig. 2 is used;

20 Figs. 8 to 10 are diagrams showing the storage states of the charges shown in Fig. 7 with regard to the green light, red light and blue light, respectively;

25 Figs. 11 to 13 are signal waveform diagrams for explaining the operation of a variable gain control circuit shown in Fig. 1;

Fig. 14 is a circuit diagram showing one example of a practical arrangement of the variable gain control circuit;

30 Fig. 15 is a signal waveform diagram showing another example of a gain control signal of the variable gain control circuit;

Fig. 16 is a diagram showing another example of the color filter array shown in Fig. 1;

35 Fig. 17 is a diagram showing the storage state of the charges on the n -th horizontal scan line in the odd field when the color filter array as shown in Fig. 16 is used;

Figs. 18 to 20 are diagrams showing the storage states of the charges shown in Fig. 17 with regard to the green light, red light and blue light, respectively;

5 Fig. 21 is a diagram showing the storage state of the charges on the $(n+1)$ th horizontal scan line in the odd fields when the color filter array as shown in Fig. 16 is used;

10 Figs. 22 to 24 are diagrams showing the storage states of the charges shown in Fig. 21 with regard to the green light, red light and blue light, respectively; and

Fig. 25 is a circuit diagram showing an arrangement of a color imaging apparatus in case of using a color filter array shown in Fig. 16.

15 An embodiment of the present invention will now be described in detail hereinbelow with reference to the drawings.

Fig. 1 is a circuit diagram showing an arrangement of a color imaging apparatus in one embodiment.

20 In the diagram, a reference numeral 10 denotes an image pick-up section. In this image pick-up section 10, a numeral 11 indicates a color filter array; 12 is a solid-state image pick-up device; and 13 is a drive circuit of this solid-state image pick-up device 12.

25 The color filter array 11 is an assembled part of color filters which are, for instance, provided for each pixel (picture element). The solid-state image pick-up device 12 is, for example, the CCD type image pick-up device. This solid-state image pick-up device 30 12 consists of a photo sensitive section array and a transfer section. The photo sensitive section array is an assembled part of photo sensitive sections which are provided in each pixel. Each photo sensitive section is formed by, e.g., a photo diode and stores 35 charges responsive to the strength of the incident light. The transfer section consists of, for example, a transfer section in the horizontal direction and a

transfer section in the vertical direction. Each transfer section is formed by a CCD.

5 The drive circuit 13 allows the charges stored in the photo sensitive section array to be transferred to the vertical transfer section and drives the horizontal and vertical transfer sections in accordance with the raster scan, thereby reading out the charges as the electrical signal from the solid-state image pick-up device 12.

10 That is, in the image pick-up section 10, a subject image formed on the photo sensitive section array as the result of that the light entered through the color filter array 11 is repeatedly horizontally scanned in a manner such that the vertical scan position is gradually
15 shifted whenever the horizontal scan ends once, thereby fetching the image as an electrical signal.

 The electrical signal which is obtained in this way is the mixed signal of a luminance signal SY and a chrominance signal SC. The chrominance signal SC
20 consists of three signals of a red signal SR, a green signal SG and a blue signal SB. The red signal SR and blue signal SB among them are the modulated signals in which the signal having the frequency of one half of the charge transfer frequency in the horizontal transfer
25 section is used as the carrier wave. In addition, the phase of the red signal SR is inverted for every horizontal scan line. On the other hand, the green signal SG is outputted not as the modulated signal but as the original signal (low frequency signal). The
30 above points will be explained in detail later.

 The above electrical signal is amplified by an amplifier 20 as necessary. An output signal of the amplifier 20 is divided into two signals and one of these signals is supplied to a low-pass filter 30 and
35 the other is supplied to a chrominance signal separating section 40. The low-pass filter 30 extracts the luminance signal SY from the input signal and supplies

it to an output terminal 50.

The chrominance signal separating section 40 has a band-pass filter 41. The band-pass filter 41 extracts the red signal SR and blue signal SB from the input signal. The mixed signal of the red signal SR and blue signal SB which is outputted from the band-pass filter 41 is supplied to an adder 42, a subtracter 43 and a delay circuit 44. The delay circuit 44 has a delay amount corresponding to one horizontal scan period (hereinafter, referred to as 1H).

The adder 42, subtracter 43 and delay circuit 44 form a comb filter. The comb filter receives an output signal from the band-pass filter 41 and delivers the red signal SR and blue signal SB as output signals. That is, since the phase of the red signal SR is inverted for every horizontal scan line, by adding, for example, the signal in the horizontal scan line which is being scanned at present (hereinbelow, referred to as the current horizontal scan line) which is outputted from the band-pass filter 41 and the signal in the horizontal scan line which was scanned 1H before (hereinafter, referred to as the previous horizontal scan line) which is outputted from the delay circuit 44 by the adder 42, the red signal SR is eliminated and the blue signal SB is obtained. On the contrary, the red signal SR is obtained from the subtracter 43.

The blue signal SB and red signal SR obtained in this way are respectively detected by detectors 60 and 70. Thus, the blue signal SB and red signal SR in the low frequency signal states are derived at terminals 80 and 90, respectively. These low frequency chrominance signals SB and SR are supplied together with the luminance signal SY which is obtained at the terminal 50 to a color encoder (not shown) and assembled into a color television signal.

The production of the chrominance signal SC in the image pick-up section 10 will then be explained.

Fig. 2 is an enlarged diagram showing a part of the color filter array 11. In the diagram, color filters 111 indicated at W1 to W4 are transparent filters which transmit the red light R, green light G and blue light B. Color filters 111 indicated at YE1 and YE2 are filters for transmitting yellow and transmit the red light R and blue light B. Color filters 111 indicated at CY1 and CY2 are filters for transmitting cyan and transmit the green light G and blue light B.

Now, when considering the image pick-up in the NTSC system as a typical example, in Fig. 2, n denotes the n -th horizontal scan line (hereinbelow, referred to as the n line) in the odd fields OF and $n+1$ likewise indicates the $(n+1)$ th horizontal scan line (hereinbelow, referred to as the $(n+1)$ line). Also, $n+263$ represents the n -th horizontal scan line (hereinafter, referred to as the $(n+263)$ line) in the even fields EF and $n+264$ similarly indicates the $(n+1)$ th horizontal scan line (hereinafter, referred to as the $(n+264)$ line).

When the storage states of the charges on the n line are classified on a color filter unit basis, their charge storage states are as shown in Fig. 3. When the stored charges are divided with regard to each of the lights G, R and B, they are as shown in Figs. 4 to 6, respectively. Similarly, the storage states of the charges on the $(n+1)$ line are as shown in Figs. 7 to 10.

In Figs. 3 to 10, an axis of ordinate indicates a storage level λ of charges. Therefore, now assuming that an axis of abscissa represents a time t , an envelope E of the charge storage level λ will indicate the chrominance signal which is outputted from the image pick-up section 10.

In the case where the color filter array 11 and horizontal scan lines are set as shown in Fig. 2, the red and blue signals SR and SB become the high frequency signals which were modulated using the carrier wave in which the period that is twice a horizontal transfer

period T is used as one period as shown in Figs. 5, 9, 6, and 10. On the contrary, the green signal SG is fetched as the low frequency signal as shown in Figs. 4 and 8.

5 In addition, in the arrangement as shown in Fig. 2, the phase of the red signal SR is inverted for every horizontal scan line as will be obvious from the comparison between Figs. 5 and 9.

10 It will be appreciated from the above description that the red signal SR and blue signal SB are extracted from among the three chrominance signals SR, SG and SB by the band-pass filter 41 in the chrominance signal separating section 40. These two chrominance signals SR and SB are outputted in the states whereby they
15 were separated by the foregoing comb filter. In this case, the respective chrominance signals SR and SB are obtained due to the addition and subtraction of the signals of two lines n and n+1, so that the amplitude levels of modulated signals become twice the amplitude
20 levels $\frac{1}{2}R$ and $\frac{1}{2}B$ of modulated signals in one line.

When the amplitude levels $2\frac{1}{2}R$ and $2\frac{1}{2}B$ of the respective chrominance signals SR and SB which are obtained from the comb line filter are expressed using equations, they are as follows.

25 In the following equations, numerals W1 to W4 used in the explanation of Fig. 2 denote the amplitude levels of the signals of transparent colors, numerals YE1 and YE2 indicate the amplitude levels of the signals of yellow, and numerals CY1 and CY2 represent
30 the amplitude levels of the signals of cyan.

$$2\frac{1}{2}B = \{(W1+W2)-(YE1+CY1)\} + \{(W3+CY2)-(YE2+W4)\}$$

..... (1)

$$= (W1+W3-YE1-YE2) + (W2-W4-CY1+CY2)$$

..... (2)

$$2\&R = \{(W1+W2)-(Y\&1+CY1)\} - \{(W3+CY2)-(Y\&2+W4)\} \\ \dots\dots (3)$$

$$= (W2+W4-CY1-CY2) + (W1-W3-Y\&1+Y\&2) \\ \dots\dots (4)$$

The first term $\{(W1+W2)-(Y\&1+CY1)\}$ in equations (1) and (3) indicates the amplitude level 1 in Fig. 3 and the second term $\{(W3+CY2)-(Y\&2+W4)\}$ denotes the amplitude level 2 in Fig. 7.

The second terms $(W2-W4-CY1+CY2)$ and $(W1-W3-Y\&1+Y\&2)$ in equations (2) and (4) are the values which will become zero if there are not the relative positional deviation between each of the above-mentioned color filters 111 and the corresponding pixel, variation in characteristics of each color filter 111, crosstalk of the stored charges between the respective pixels, etc. Therefore, in this case, the amplitude levels 2B and 2R become the normal values which are specified by the first terms $(W1+W3-Y\&1-Y\&2)$ and $(W2+W4-CY1-CY2)$ in equations (2) and (4), respectively.

However, it is fairly difficult to eliminate the above-mentioned positional deviation, variation in characteristics, crosstalk, etc., so that the second terms in equations (2) and (4) become the error components of the amplitude levels 2B and 2R, respectively.

Although the above description relates to the odd fields OF, a similar processing is also performed with regard to the even fields EF. The amplitude levels 2B and 2R of the blue signal SB and red signal SR which are derived due to this processing will be as shown in the following equations, respectively.

$$2\&B = \{(W2+W3)-(CY1+Y\&2)\} + \{(CY2+W1)-(W4+Y\&1)\} \\ \dots\dots (5)$$

$$= (W1+W3-Y\&1-Y\&2) + (W2-W4-CY1+CY2) \\ \dots\dots (6)$$

$$2\&R = \{(W2+W3)-(CY1+YE2)\} - \{(CY2+W1)-(W4+YE1)\}$$

..... (7)

$$= (W2+W4-CY1-CY2) - (W1-W3-YE1+YE2)$$

..... (8)

5

The second terms in equations (6) and (8) are respectively the error components at the amplitude levels 2&B and 2&R similarly to the foregoing equations (2) and (4).

10

As will be apparent from equations (2) and (6), the signs (+ and -) of the error components of the amplitude level 2&B are the same with regard to both odd fields OF and even fields EF. Therefore, the amplitude level 2&B of the blue signal SB is the same regarding both odd fields OF and even fields EF.

15

Contrarily, the signs of the error components at the amplitude level 2&R are (+) in the odd fields OF and (-) in the even fields EF. Consequently, the amplitude level 2&R of the red signal SR varies depending upon the odd fields OF and even fields EF.

20

Such a phenomenon occurs even if filters for transmitting green is used in place of transparent filters W1 to W4.

25

The change of the amplitude level 2&R of the red signal SR in the odd fields OF and even fields EF causes the color flicker at 30 Hz in the image.

30

Therefore, in this invention, the occurrence of color flicker is prevented by controlling the amplitude level 2&R of the red signal SR which is outputted from the subtracter 43 for every field.

35

In the embodiment of Fig. 1, a variable gain control circuit 100 is inserted between the output terminal of the subtracter 43 and the input terminal of the detector 70. The variation in the amplitude level 2&R of the red signal SR which is inputted to the detector 70 is eliminated by changing the gain of the variable gain control circuit 100 with respect to the

odd fields OF and even fields EF.

A field index signal FI is used as a signal to control the gain of the variable gain control circuit 100. This field index signal FI is the square wave at 30 Hz to discriminate the odd fields OF and even fields EF and is produced by the drive circuit 13. This drive circuit 13 has a reference signal generator and produces a pulse to drive the horizontal and vertical transfer sections in the solid-state image pick-up device on the basis of an output signal of this reference signal generator. At this time, the field index signal FI is produced for, for example, change-over of the scan of the odd fields OF and even fields EF.

The gain control operation of the variable gain control circuit 100 will then be explained with reference to Figs. 11 to 13. Fig. 11 shows the red signal SR which is outputted from the subtracter 43. Fig. 12 shows the field index signal FI. Fig. 13 shows the red signal SR which is outputted from the variable gain control circuit 100. Also, Figs. 11 to 13 show the red signal output in the case where, for example, a white subject was imaged.

As shown in Fig. 12, the field index signal FI is the binary level signal of which the level is inverted for every field. Therefore, if the gain of the variable gain control circuit 100 is controlled in accordance with the amplitude level of the field index signal FI, different gains can be set with regard to the odd fields OF and even fields EF. Thus, if the set gains for the odd fields OF and even fields EF are preliminarily properly adjusted, the red signal SR in which the amplitude levels regarding the odd fields OF and even fields EF are equal can be obtained from the variable gain control circuit 100 as shown in Fig. 13, thereby enabling the occurrence of color flicker at 30 Hz to be prevented.

For instance, a differential amplifier as shown

in Fig. 14 may be used as the variable gain control circuit 100.

In Fig. 14, numerals 101 and 102 denote transistors forming a differential pair and 103 indicates a transistor forming a constant current source for the
5 transistors 101 and 102.

The operation of this circuit will now be explained. The red signal SR applied to an input terminal 104 from the subtracter 43 is supplied through
10 a capacitor 105 to the base of the transistor 101. After this red signal was differentially amplified by the transistors 101 and 102, it is supplied to an output terminal 106 from the collector of the transistor 102 as the signal having the same phase as that of the
15 red signal SR at the input terminal 104.

The field index signal FI is supplied to the base of the transistor 103 through an input terminal 107. Due to this, the collector current of the transistor 103 is controlled by the amplitude level of the field index
20 signal FI. As will be obvious from the comparison between equations (4) and (8), the amplitude level of the red signal SR in the even fields EF is smaller than the amplitude level of the red signal SR in the odd fields OF. The amplitude level of the field index
25 signal FI is set to a high level in the even fields EF and to a low level in the odd fields OF as shown in Fig. 12. With the field index signal at a low level, a gain in the differential amplifier is set to be equal to a reference gain. In this connection it is to be noted
30 that the gain in the differential amplifier becomes greater than the reference gain when the field index signal FI is at a high level. By so doing, the red signal SR on the even field EF is amplified to a greater extent than the red signal SR on the odd field OF to
35 permit the amplitude level of the red signal SR on the even field EF to be made equal to that of the red signal SR on the odd field OF.

On the other hand, with the field index signal FI at a high level, i.e., with the even field EF, the gain in the differential amplifier may be set to be equal to the reference gain. In this connection it is to be noted that the gain in the differential amplifier becomes lower than the reference gain with the field index signal at the lower level, i.e., with the odd field OF. In Fig. 14, (+B) denotes a power supply.

The invention is not limited to the foregoing embodiment.

For instance, as the gain control signal for the variable gain control circuit 100 which is applied from the drive circuit 13, it is not limited to the field index signal FI, but any signal synchronized with the change-over timing of the fields may be used irrespective of its waveform. For example, as shown in Fig. 15, pulses of a single polarity (pulses of the positive polarity in the diagram) which are generated synchronously with the time at which the change-over is made from odd field OF to even field EF may be used. Even in case of such pulses, for example, if a square wave at 30 Hz is obtained by providing a monostable multivibrator for the variable gain control circuit 100 and by driving this monostable multivibrator by the above pulses, such gain control as mentioned above can be performed.

Also, obviously, the variable gain control circuit 100 is not limited to the current control type differential amplifier. For instance, it is possible to use a circuit of an arrangement such that the gain is controlled by switching the load at the cycle of 60 Hz.

In addition to the purpose for prevention of occurrence of the color flicker, the variable gain control circuit 100 may be commonly used in an γ correction circuit which likewise uses a variable gain control circuit.

Also, the variable gain control circuit 100 may be

arranged at the post stage of the detector 70, thereby controlling the amplitude level of the red signal SR in the state of the low frequency signal. In this connection, it is to be noted that, when the differential amplifier as shown in Fig. 14 is used as the variable gain control circuit 100, it is better to control the amplitude level $2\&R$ of the red signal SR in the state of high frequency signal. Because, it is possible to reduce an interference of the gain control signal over the red signal due to the frequencies of the two signals being greatly separated from each other. Even if the amplitude level of the red signal SR is controlled by the differential amplifier in the state of low frequency signal, the interference of the gain control signal over the red signal SR can be made as small as possible through the use of a double balanced differential amplifier as the differential amplifier.

The level control means is not limited to the variable gain control circuit. For example, two circuits with different gains may be used such that they are switched in dependence upon the odd fields OF and even fields EF.

The change-over of the above two circuits with different gains and the change-over of the gains in the variable gain control circuit may be made of effecting an initialization by external synchronization. In this connection, it is to be noted that the synchronizing operation so initialized is subsequently carried out by an internal synchronization.

This invention may be also applied to a color imaging apparatus which permits light from the subject to be taken therein by means of a color filter array other than that shown in Fig. 2. In the diagram, color filters indicated at G1 and G2 are filters for transmitting the green light. The storage state of charges on the n line in this case is as shown in Fig. 17. On one hand, when the stored charges are classified with

respect to each of the lights G, R and B, the storage states of the charges are as shown in Figs. 18 to 20, respectively. Likewise, the storage state of charges on the (n+1) line is as shown in Fig. 21 and the storage states of the charges regarding each of the lights R, G and B are as shown in Figs. 22 to 24, respectively.

In a color filter array 11 of the arrangement in Fig. 16, different from the color filter array 11 in Fig. 2, the chrominance signal whose phase is inverted for every horizontal scan line becomes the blue signal SB. Therefore, in this case, in Fig. 1, the red signal SR is outputted from the adder 42 and the blue signal SB is outputted from the subtracter 43.

The amplitude levels 2&R and 2&B of the red signal SR and blue signal SB in the odd fields OF are expressed by the following equations (9) and (10), respectively.

$$2\&R = (W1-G1) + (YE1-CY1) \quad \dots\dots (9)$$

$$2\&B = (W1-G1) - (YE1-CY1) \quad \dots\dots (10)$$

Similarly, the amplitude levels in the even fields EF are expressed by the following equations (10) and (11).

$$2\&R = (W2-G2) + (YE2-CY2) \quad \dots\dots (11)$$

$$2\&B = (W2-G2) - (YE2-CY2) \quad \dots\dots (12)$$

As will be obvious from equations (9) to (12), in the color filter array 11 in Fig. 16, the amplitude levels 2&R and 2&B of any of the red signal SR and blue signal SB are specified by the color filters 111 which quite differ with regard to the odd fields OF and even fields EF. That is, in case of any of the red signal SR and blue signal SB, the amplitude levels 2&R and 2&B are specified by the color filters 111 indicated at numerals W1, G1, YE1, and CY1 in the odd fields OF. On the contrary, in the even fields EF, they are specified by the color filters 111 which are indicated at numerals W2, G2, YE2, and CY2. This means that the amplitude

levels 2&R and 2&B of both red signal SR and blue signal SB change in dependence upon the odd fields OF and even fields EF. Therefore, in this case, it is necessary to control the amplitude levels 2&R and 2&B of both red
5 signal SR and blue signal SB for every field. This problem can be solved by providing a variable gain control circuit 110 also on the output side of the adder 42, for example, as shown in Fig. 25.

This invention can also be applied to a color
10 imaging apparatus using the image pick-up tube.

As described above, according to the invention, since the amplitude level of a separated replica of the chrominance signal is controlled for every field, the occurrence of the color flicker at 30 Hz is
15 suppressed to a minimum possible extent. Due to this, the image pick-up section can be easily manufactured and this can contribute much to an improvement in yield.